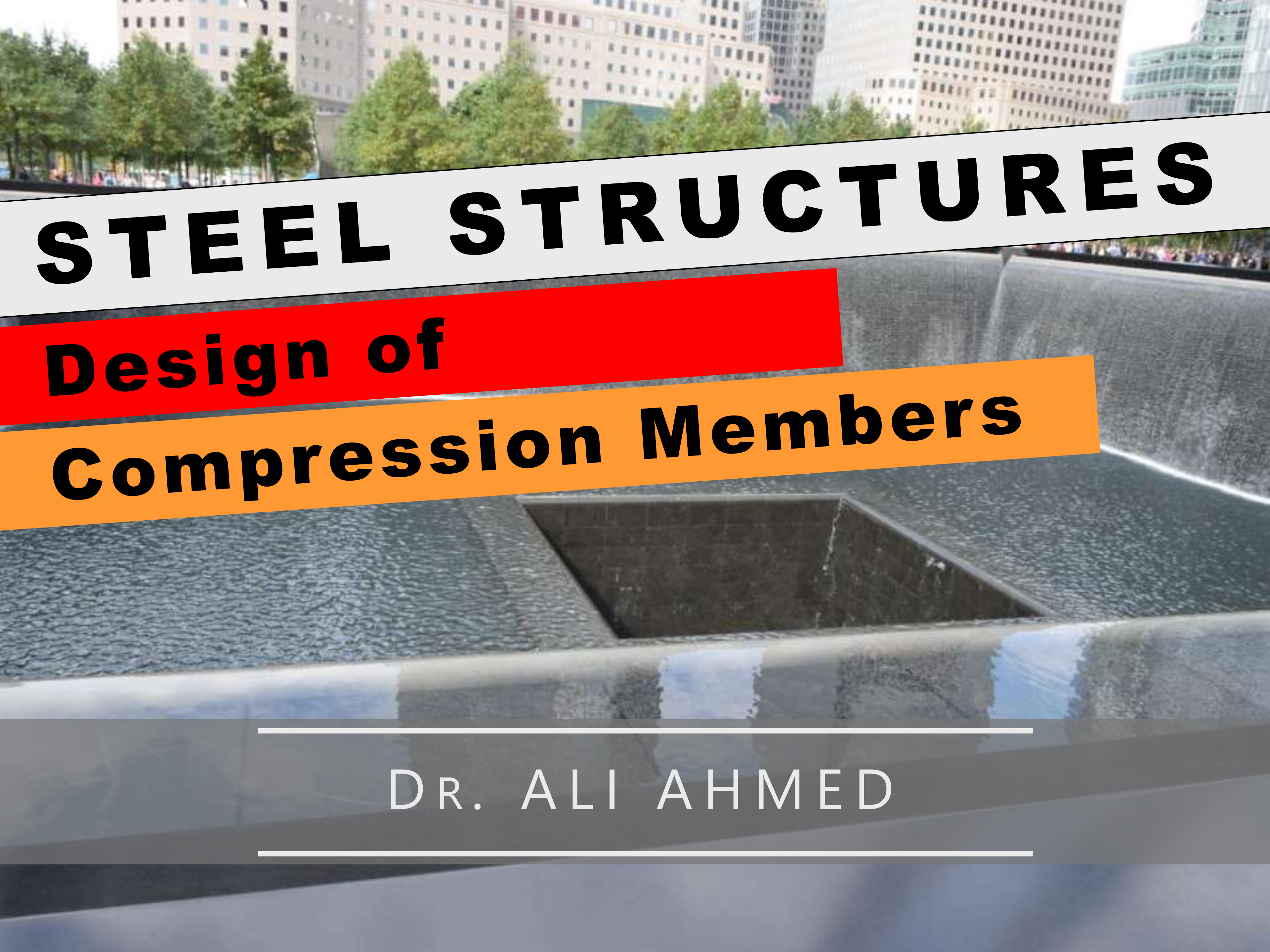

STEEL STRUCTURES

Design of Compression Members

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CHAPTER # 3

DESIGN OF COMPRESSION MEMBERS

2/3

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CORRECTION FOR SINGLE ANGLES

FOR PLANAR TRUSSES

Single angle compression members may undergo *torsional buckling* at loads lower than the loads at which buckling may occur about ***x***, ***y*** or ***z*** axes.

Hence, in order to closely estimate the capacity of equal leg angles or unequal leg angles connected through the longer leg, the slenderness ratio is to be modified as under:

(i) When $0 \leq L / r_x \leq 80$

$$KL/r = 72 + 0.75\, L / r_x$$

(ii) When $L / r_x > 80$

$$KL/r = 32 + 1.25\, L / r_x \leq 200$$

DESIGN FLOW CHART FOR COMPRESSION MEMBERS

Known Data / Inputs

P_D , P_L , L, end conditions (*K-value*) *etc.*

↓

Calculate P_u for the controlling/critical load combination. Also find the values of effective length factor K_x, K_y and K_z.

↓

Assume slenderness ratio

(if column selection tables are not to be used)

$R \approx 115$	for single angle or channel sections
$R \approx 90$	for double angle or W sections
$R \approx 70$	for built-up sections
$R \approx 35$	for section continuously braced in the lateral direction

↓

Find $\phi_c F_{cr}$ from table in ***Reference-1 (Page 105-110)*** , or by employing the appropriate formulas, depending on the assumed slenderness ratio.

↓

Calculate area required for the assumed slenderness ratio.

Accordingly the ***selected area may be a little greater or lesser than the calculated required area***. This may be different from the value for the actual slenderness ratio unknown at this stage and may be on the conservative or unsafe side of the actual value.

$$A_{req} \approx \frac{P_u}{\left(\phi_c F_{cr}\right)_{ass}}$$

Selection of Trial Section

Use either the column selection tables ***(Refrence-1, Page111-154)*** or adopt the trial and error procedure.

Following criteria are to be satisfied:

a) $A_{sel} \approx \pm A_{req}$

b) The section must have minimum possible weight.

c) Connected leg width for various types of connections ($\boldsymbol{b_{min}}$) is selected using one of the following expressions as applicable:

i. L/40 for L = 2 to 3 meter
ii. 3.25d + 18
iii. $\geq$ 50 mm for welded connections

where d = diameter of rivets, may be assumed equal to 15mm if not known.

d) Maximum depth of column section should generally not exceed 360mm (14in) for W sections.

Calculate Critical Slenderness Ratio

Find unsupported length in each direction $\boldsymbol{L}_{\mathbf{ux}}$, $\boldsymbol{L}_{\mathbf{uy}}$ and $\boldsymbol{L}_{\mathbf{uz}}$

Calculate the radii of gyration **(*r_x*, *r_y*, *r_z*)** or directly see their values from the properties of sections table.

Calculate $\dfrac{K_x L_{ux}}{r_x}$, $\dfrac{K_y L_{uy}}{r_y}$ and $\dfrac{K_z L_{uz}}{r_z}$

R = maximum value out of the above slenderness ratios

Perform Local Stability Check

Examine $\lambda = b/t$ ratios for stiffened and un-stiffened elements of the section and the following must be satisfied:

$$\lambda \leq \lambda_r \qquad\qquad \textbf{\textit{OK}}$$

For A36 Steel: *(Reference-1, Page 313)*

λ_r = 12.7 for single angles and double angles with separators

λ_r = 15.8 for other un-stiffened elements

λ_r = 42.1 for stiffened elements

⇓

Perform Maximum Slenderness Check

$R \leq 200$ *OK*

Otherwise revise by selection of another trial section.

R greater than 200 may be allowed in special cases as per AISC recommendations.

Compressive Capacity ($\phi_c P_n$) For KL/r > 200

$$P_u < \underbrace{0.75 \times 0.9}_{\phi_c} \times \underbrace{0.877 \frac{\pi^2 E}{(KL/r)^2}}_{F_e} A_g \times \underbrace{\frac{1}{1000}}_{\text{To convert the result into kN}}$$

The additional factor of 0.75 is used to exceed the AISC recommended limit of 200.

$$\Rightarrow (KL/r)^2 \leq \frac{1169}{P_u}.A_g$$

$$\Rightarrow \frac{KL}{r} \leq 34\sqrt{\frac{A_g}{P_u}}$$

Find $\phi_c F_{cr}$ from tables in ***Reference-1*** or using formulas.

Perform Capacity Check

$$\phi_c F_{cr} . A_{sel} \geq P_u \qquad O\,K$$

Otherwise revise after fresh selection of section.

Check For Reversal Of Stresses

If $T_u > 0$, check that $\phi_t T_n \geq T_u$

Otherwise Revise

Check For Loading Cycles

Assume that loading cycles are lesser than 20,000 for ordinary buildings.

↓

Design Stay Plates or Lacing.

↓

Write Final Selection using Standard Designation

ALTERNATE AND EASY METHOD TO SELECT TRIAL SECTION

W-Sections

Load carrying capacities ($\phi_c P_n$) for various W-sections against the values of effective lengths with respect to least radius of gyration are tabulated in Reference-1 *(Page111-137)*.

Corresponding to the value of effective length $K_y L_{uy}$, a section may be selected when the tabulated $\phi_c P_n$ becomes just greater than P_u while moving from left to right in the table.

Few sections with different depths may be examined to find a minimum weight section.

To check stability of the section about the *x* – axis, K_xL_x is converted into an equivalent K_yL_y by using the following expression:

$$\left(K_yL_y\right)_{eq} = \frac{K_xL_x}{r_x / r_y}$$

where r_x / r_y is used for the previously selected section.

The ratio r_x / r_y included in these tables provides a convenient method for investigating the strength of a column with respect to its major axis.

Section is selected / revised for longer of the two lengths K_yL_y and $(K_yL_y)_{eq}$.

The procedure is explained as under:

Procedure

1. Find maximum values of K_xL_x and K_yL_y.
2. Select section against K_yL_y according to the loads *starting from W360 side and moving downward by weight*.
3. Find r_x / r_y for the selected section and calculate equivalent K_yL_y as $K_xL_x/(r_x / r_y)$.
4. Re-enter the table for greater value out of K_yL_y and $(K_yL_y)_{eq}$.
5. Revise the section if necessary.

Example 3.1: Design a truss compression member using the following three given cross-sectional shapes:

1. 2Ls with 10 mm thick gusset plate and bolted stay plates.
2. Single angle.
3. W-section.

The other data is as under:

P_D = 110 kN ; P_L = 140 kN

L = 3.4 m ; A36 Steel

Solution:

The truss member consisting of double angles along with the gusset plate is shown in Figure 3.18.

For truss members, $K = 1$

$L_u = L$ as there is no bracing between the joints

2- *Single Angle*

Single angle can undergo lateral torsional buckling. Separate AISC provisions are applicable for such design.

Equal leg angles are generally preferred for single angle columns in case the two effective lengths K_xL_x and K_yL_y are equal.

However, unequal leg angles may also be used if the resulting section comes out to be economical.

$P_u = 356$ kN, $R_{ass} = 125$

$(\phi_c F_{cr})_{ass} = 98.28\ Mpa$ Reference-1 ***(Page 106)***

$$Area_{req} = \frac{P_u \times 1000}{\phi_c F_{cr}} = \frac{356 \div 1000}{98.28} = 3623, mm^2$$

Select section based on the following parameters:

1. $A_{sel} \approx A_{req}$
2. *Minimum weight section*
3. $b \geq b_{min} = 67$ mm
4. *Equal legs will be preferred as K_xL_x and K_yL_y are equal.*

Options Available: (Using selection table)

L127x127x15.9, Area = 3780, Weight = 29.8 kg/m

L152x152x12.7, Area = 3780, Weight = 29.2 kg/m

***Trial Section:* L 152×152×12.7 (due to lesser weight)**

The most convenient method is to use the ***Column Selection Table*** for ***Single Angle Section*** ***(Reference-1, Page 149)***

Section	$\phi_c P_n$ **(kN)**	***KL* (m)**	**Area (mm²)**
L 152×152×12.7	390.7 352.1 359.8	$KL_z = 3.0$ $KL_z = 3.5$ $KL_z = 3.4$ **by interpolation**	**3710**

r_x = 47.2 mm ; r_z = 30 mm ; $A = 3710\ mm^2$

Check for b_{min}: $b = 152 > b_{min} = 67$ **(OK)**

Check for Local Instability:

$$\lambda = b / t = 152/12.7 = 11.98 < \lambda_r = 12.7 \quad \textbf{(OK)}$$

Stability Check:

$$\frac{KL}{r_z} = \frac{3400}{30} = 114$$

$$L / r_x = 3400 / 47.2 = 72.03 \leq 80$$

$$KL/r = 72 + 0.75\, L / r_x$$

$$= 72 + 0.75 \times 72.03 \cong 126$$

Formula is also given on Reference-1 *Page 314*

Maximum Slenderness Ratio Check:

R value is larger of KL/r_z and KL/r = **126** < **200** **(OK)**

Capacity Check:

From table of Reference-1 ***(Page 106)***:

For R = 126,

$\phi_c F_{cr} = 96.98$ MPa

$\phi_c F_{cr} A_{sel} = 96.98 \times 3710 / 1000$

$= \mathbf{359.80}\ kN > P_u = \mathbf{356}\ kN$ ***(OK)***

Assuming Loading cycles are lesser than 20,000.

Final Selection

L 152x152x12.7

3- W-Section

P_u = 356 kN, R_{ass} = 90

$(\phi_c F_{cr})_{ass} = 146.46\ Mpa$ *(Reference-1, Page 106)*

$$Area_{req} = \frac{P_u \times 1000}{\phi_c F_{cr}} = \frac{356 \div 1000}{146.46} = 2431, mm^2$$

Select section based on the following parameters:

1. $A_{sel} \approx A_{req}$
2. *Minimum weight section*
3. $b \geq b_{min}$ = 67 mm
4. *Depth (d)* $\leq 360mm$

Using the **W-shape selection tables** ***(Reference-1 Page 122)*** for P_u = 356 kN, K_yL_y = 3.4m, following option is obtained [$(K_yL_y)_{eq}$ is not critical as member has the same L_{ux} & L_{uy}]

Trial Section: **W150 × 22.5**

$r_x = 65$; $r_y = 37.1$; $A = 2860 \text{ mm}^2$

Check for b_{min}:

$$b_f / 2 = 152/2 = 76 \text{ mm} > b_{min} = 67 \quad \textbf{(OK)}$$

Check for Local Instability:

$$\lambda = \frac{b_f}{2t_f} = 11.5 < \lambda_r = 15.8 \quad \textbf{(OK)}$$

$$\lambda = \frac{h}{t_w} = 21.6 < \lambda_r = 42.1 \quad \textbf{(OK)}$$

Maximum Slenderness Ratio Check:

$$R = \frac{K\ell}{r_{min.}} = \frac{3.4 \times 1000}{37.1} \cong 92 < 200 \quad \textbf{(OK)}$$

Capacity Check:

From table of Reference-1 ***(Page 106)***:

For R = 92,

$\phi_c F_{cr}$ = 143.66 MPa

$\phi_c F_{cr} A_{sel}$ = 143.66 × 2860 / 1000

= 410.87 *kN* > P_u = 356 *kN* ***(OK)***

Assuming Loading cycles are lesser than 20,000.

Final Selection

W 150x22.5